Claims

1. A device to regular current produced by an induction machine comprising:

an induction motor responsive to a plurality of phase current signals, said motor producing torque for application on a shaft;

a processing and drive circuit responsive to a direct current command signal and a quadrature current command signal, said processing and drive circuit for producing a plurality of phase current signals for input into said induction motor;

a command circuit responsive to said plurality of phase current signals, to an angular position of said shaft, and to a current input command signal for producing a direct current error signal and a quadrature current error signal;

a control circuit responsive to the direct and quadrature current error signals for producing direct and quadrature voltage signals; and

a limiter for limiting the direct and quadrature voltage signals to a selected level.

2. The device of claim 1 including a D-axis current command circuit responsive to a torque command, Torque*, one of a zero time vector, T0*, a time for voltage vector, T1+T2*, and a voltage magnitude Vmag* and one of a feedback for zero time vector, T0, time for voltage vector, T1+T2, and voltage magnitude Vmag.

3. The device of claim 1 further including a transform circuit responsive to phase current signals of the drive circuit to produce direct and quadrature synchronous current feedback signals Idsf and Iqsf.

4. The device of claim 1 including a Q-axis current command circuit responsive to a torque command, Torque*, and a feedback D-axis current, Idsf, for producing a Q-axis current command.

5. The device of claim 1 wherein said command circuit includes, a control circuit responsive to said direct and quadrature current error signals to produce said direct voltage command signal and said quadrature command signal, said control circuit having a first portion and a second portion, wherein said first portion includes a first pathway having a first proportional gain and a second pathway having a first integrator and a first clamp, and a third pathway having a first summing node and a second clamp, wherein said second portion includes a fourth pathway having a second proportional gain and a fifth pathway having a second integrator and a third clamp and a sixth pathway having a second summing node and a fourth clamp.

6. The device of claim 5 wherein said first portion produces said direct voltage command signal, and said first and second clamps contain said voltage Vds MIN. $\leq$ Vds $\leq$ Vds MAX.

7. The device of claim 5 wherein said second portion produces said quadrature voltage command signal, and said third and fourth clamps contain said voltage Vqs MIN. $\leq$ Vqs $\leq$ Vqs MAX.

8. The device of claim 1 wherein said direct current error signal is produced by subtracting a direct synchronous current feedback signal from a direct synchronous current command signal.

9. The device of claim 2 further including a proportional integrator responsive to a zero time vector feedback T0 and a zero time vector command T0* for producing an output, and a limiter responsive to the output for producing a D-axis time zero signal, IdsT0, between zero and a selected value; a maximum torque per ampere circuit for producing a D-axis current look up signal, IdsLUT; a summing circuit responsive to the D-axis time zero signal and the D-axis current look up signal to produce a D-axis current command Ids*

10. The device of claim 1 further comprising in a motor mode means for determining the angle representing a sensed direction of the vector, means for determining a maximum angle of said vector and means for recalculating the voltages to a limited value based on the maximum angle and setting the slip frequency to a maximum value which is a function of the rotor speed, when the sensed angle exceeds the maximum angle.

11. The device of claim 1 further comprising means for calculating the slip frequency as a function of direct and quadrature synchronous current feedback signals.

12. The method of claim 1 further comprising means for determining in a generating mode the angle representing a sensed direction of the vector, means for determining a minimum angle of said vector and means for recalculating the voltages to a limited value based on the minimum angle and setting the slip frequency to a minimum value which is a function of the rotor speed, when the sensed angle is less than the minimum angle.

13. A method to regulate current produced by an induction machine comprising limiting each of the respective direct and quadrature voltages Vds and Vqs to selected value range which together represent the magnitude and direction of a resulting voltage vector.

14. The method of claim 13, wherein the vector comprises $\sqrt{Vds^2 + Vqs^2}$, or K(1-T0), or K(T1+T2)

15. The method of claim 13 wherein the direction of the vector comprises

arc tan -Vds/Vqs, the voltage angle relative to Q axis.

16. The method of claim 13 further comprising calculating a synchronous angle θ_e by differentiating a rotor position signal to derive rotor speed, selecting a maximum slip frequency based on the rotor speed, adding the rotor speed and slip frequency to produce synchronous frequency speed and integrating the synchronous frequency to produce a synchronous position angle θ_e.

17. The method of claim 13 further comprising determining in a motor mode the angle representing a sensed direction of the vector, determining a maximum angle of said vector and recalculating the voltages to a limited value based on the maximum angle and setting the slip frequency to a maximum value which is a function of the rotor speed, when the sensed angle exceeds the maximum angle.

18. The method of claim 13 further comprising calculating the slip frequency as a function of direct and quadrature synchronous current feedback signals.

19. The method of claim 13 further comprising determining in a generating mode the angle representing a sensed direction of the vector, determining a minimum angle of said vector and recalculating the voltages to a limited value based on the minimum angle and setting the slip frequency to a minimum value which is a function of the rotor speed, when the sensed angle is less than the minimum angle.

20. A method to regulate current produced by an induction machine comprising the steps of:

inputting a direct current command signal and a direct current feedback signal into a first circuit;

subtracting said direct current feedback signal from said direct current command signal to produce a first direct current error;

inputting said direct current error signal into a first proportional controller to produce a first direct voltage signal command;

inputting said direct current error signal into a first integrator to produce a second direct voltage signal command;

inputting said second direct voltage signal command into a first limiter to produce a third direct voltage signal command;

adding said third direct voltage signal command with said first direct voltage signal command to produce an unclamped direct voltage signal command;

inputting said unclamped direct voltage signal command into a second limiter to produce a direct synchronous voltage signal command;

inputting a quadrature current feedback signal and a quadrature current command signal into a second circuit;

subtracting said quadrature current feedback signal to said quadrature current command signal to produce a quadrature current error signal;

inputting said quadrature current error signal into a second proportional controller to produce a first quadrature voltage signal command;

inputting said quadrature current error signal into a second integrator to produce a second quadrature voltage signal command;

inputting said second quadrature voltage signal command into a third limiter to produce a third quadrature voltage signal command;

adding said third quadrature voltage signal command with said first quadrature voltage signal command to produce an unclamped quadrature voltage signal command; and

30 inputting said unclamped quadrature voltage signal command into a fourth limiter to produce a quadrature synchronous voltage signal command.

21. The method of claim 20 wherein said third direct voltage signal command represents a steady state value and said first limiter clamps the value of said third direct voltage signal command to be no greater than a selected maximum value and to be no less than a selected minimum value.

22. The method of claim 20 wherein said second limiter clamps the value of unclamped said direct voltage signal command to be no greater than a selected maximum value and to be no less than a selected minimum value.

23. The method of claim 20 wherein said third direct quadrature voltage signal command represents a steady state value and said third limiter clamps the value of said third quadrature voltage signal command to be no greater than a selected value and to be no less than a selected minimum value.

24. The method of claim 20 wherein said fourth limiter clamps the value of said unclamped quadrature voltage signal command to be no greater than a selected value and to be no less than a selected minimum value.

25. A device to regulate current produced by an induction machine comprising:

an induction motor responsive to a plurality of phase current signals, said motor producing torque for application on a shaft;

a processing and drive circuit responsive to a direct current command signal and a quadrature current command signal, said processing and drive circuit for producing a plurality of phase current signals for input into said induction motor;

a command circuit responsive to said plurality of phase current signals, to an angular position of said shaft, and to a current input command signal for producing a direct current error signal and a quadrature current error signal; and

a control circuit responsive to said direct and quadrature current error signals, said control circuit having a first portion and a second portion, wherein said first portion includes a first proportional integrator and a first clamp means connected thereto, for producing the direct voltage signal command, said second portion includes a second proportional integrator and second clamp means connected thereto for producing the quadrature direct voltage signal command.

26. A method for regulating current produced by an induction machine driven by direct and quadrature signals comprising the steps of:

subtracting a direct current signal from a direct current signal command to produce a first direct error signal;

proportionally integrating the direct error signal to produce the proportionally integrated direct signal command;

limiting the proportionally integrated first direct signal command to produce the direct signal command;

subtracting a quadrature current signal from a quadrature current signal command to produce a quadrature direct error signal command;

proportionally integrating the quadrature signal command to produce a proportionally integrated quadrature signal command;

limiting the proportionally integrated quadrature signal to produce a quadrature signal command.